THE McCLURE MOUNTAIN SYENITIC COMPLEX OF COLORADO

A Senior Thesis

Presented in Partial Fulfillment of the Requirements
for the Degree Bachelor of Science

by

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Introduction

The Wet Mountains occupy approximately 50 miles of south central Colorado as an en echelon extension of the Colorado Front Range. This southwest trending mountain range occupies most of Fremont and Custer Counties running from Greenhorn Mountain, in the south, to near Canon City, 35 miles southwest of Colorado Springs, in the north.

Rocks found in the Wet Mountain area include metamorphosed Precambrian basement rocks and igneous rocks of at least two ages. They are bounded by sedimentary rocks Tertiary and younger in age. Unconformities are prevalent, at least four being present in the sedimentary sequence (Taylor et al, 1975). Upper Cenozoic rocks also include volcanic tuffs and alluvium although these are poorly exposed. These rocks will be discussed in detail at a later time.

The Wet Mountains are a result of tensional block faulting in the Precambrian and again in the Cretaceous (Kent et al, 1977). This tension allowed movement along nearly vertical fractures which cut Cretaceous and older rocks. Many of these faults are Precambrian and were reactivated by Laramide activity during the Cretaceous.

Relatively little has been written concerning the geology of the Wet Mountains in general or the McClure Mountain Complex in particular. Much of the previous work involves the thorium deposits or the composition of the intrusive bodies present in the area. Christman and others

(1959) and Singewald and Brock (1975) have used these thorium deposits and the associated igneous bodies to radiometrically date the intrusives in the area. They have found the bodies to be early Proterozoic in age.

Some of the work has been done to try to discover the cause of the intrusive episodes. LeBas (1971) believes these to be a result of tensional forces. Baily (1962) attributed the igneous activity to compressional, rather than tensional, forces. He belived that compressional and vertically acting forces caused upbulging of the crust and compressional arching. A third theory (Olson et al, 1977) attributes the igneous bodies to either the movement of crust over a localized hot spot or, conversely, the migration of a localized source of volatile enrichment.

Some of the previous work deals with the composition of the intrusive bodies found in the Wet Mountains. Parker and Hildebrand (1962) discussed the composition of the alkalic intrusive rocks in the northern section of the Wet Mountain area whereas Alexander and Heinrich (1978), Parker and Sharpe (1970), Heinrich and Dahlem (1967) and Shawe and Parker (1967) covered only the igneous rocks found in Custer and/or Fremont counties. An article by Armbrustmacher related only to the occurrence of primary carbonatites within the mountains.

Other work which deals with the area includes MacPherson (1981) who studied the occurrence of uranium in

Fremont County. Singewald and Brock (1965) and Christman and others (1959) studied the thorium deposits present in the area. Several works deal with isotope measurements in the area. These include Powell and Bell (1970), Armbrustmacher and Hedges (1982) and Hedlund and Olson (1961).

It is the authors purpose to describe the igneous history of the rocks found in the McClure Mountain Complex. This includes identification of the rocks present and determination of parent magma composition. Conclusions will also be drawn as to the forces which resulted in the igneous emplacement.

General Geology

In the Wet Mountain area, the basement consists of a wide variety of metamorphic rocks of early Proterozoic, or Precambrian X, age (see Table 1). Most prevalent is a layered migmatitic gneiss resulting from the metamorphism of sediments and associated rhyodacitic flows and tuffs. The lithology of these rocks prior to metamorphism has not been stated in the literature. The predominant composition of these metamorphic rocks is biotite-quartz-plagioclase gneiss although some layers contain hornblende gneiss or calcsilicate gneiss (Taylor et al, 1975). This gneiss is usually gray in color but ranges to pink or tan.

A light gray granodiorite and a dark gray quartz diorite also occur in the area. The Precambrian X rocks are of Boulder Creek age, 1729 m.y. (Armbrustmacher and Hedges, 1982). The granodiorite occurs as large plutons roughly

Subdivision	Age
Precambrian Z	Base of Cambrian to 800 m.y.
Precambrian Y	800 m.y. to 1,600 m.y.
Precambrian X	1,600 m.y. to 2,500 m.y.
Precambrian W	older than 2,500 m.y.

Table 1: Precambrian Subdivisions

From: Taylor and others (1975).

three miles in diameter within the Wet Mountains but nearly 12 miles in diameter slightly farther north. It is massive within the plutons and foliated at pluton margins. This granodiorite is composed of oligoclase, microcline and hornblende with small amounts of biotite and/or quartz. The quartz diorite occurs mainly as a shell around some of the larger plutons of granodiorite. Where associated with the granodiorite, it occurs as a gradational extension of the granodiorite and is well foliated. It also occurs independently in small plutons, less than one mile in diameter, where it is massive. These Boulder Creek age plutons are found scattered throughout the Wet Mountains area and beyond.

Cambrian rocks are composed dominantly of intrusive bodies although two varieties of breccia are associated. Both breccias contain clasts composed of Precambriam metamorphics but one breccia has a matrix composed of lamprophyre whereas the other contains syenite.

Igneous intrusives of various compositions occur within the Wet Mountains. At Democrat Creek, a light- to mediun-gray syenite is found which contains small amounts of quartz. Also found are minor amounts of amphibole-rich mafic variants and olivine-clinopyroxene gabbro (Christman et al, 1959). A major syenite intrusion forms the McClure Mountain Complex. The syenite composition ranges from biotite-hornblende syenite to nepheline syenite. Also present are olivine gabbro, mafic nepheline-bearing rocks and carbonatites. A question still exists as to whether or not these rocks originated from the same magma or formed part of the same stock. These rocks will be described in detail in a later section.

The next sequence of rocks spans the Paleozoic and Mesozoic and consists of intermittently deposited sedimentary rocks. This sequence begins with Ordovician and Mississippian sediments. These include the Manitou Limestone, Harding Sandstone, Fremont Dolomite and Williams Canyon Limestone. These formations range from inches thick, for the Manitou Limestone, to 283' thick, for the Fremont Dolomite. A Permian arkose conglomerate occurs above this sequence. This conglomerate contains pebbles of Precambrian metamorphics along with thin layers of green and red-brown shale. The Morrison Formation (JR) is present in this area as gray, maroon and green siltstones and claystones. Other Jurassic rocks include arkosic conglonerates, siltstones, sandstones and gypsum. These rocks all form the Ralston Creek Formation.

Cretaceous rocks also of sedimentary origin are found. Yellow cross-bedded sandstones give way to green limestones and shales. These intertonguing facies vary widely in lithology from thinly laminated yellow shales, to gray calcarenite to black shales containing bentonite and fossils (Taylor et al, 1975).

Exposures of Tertiary rocks are scattered throughout the Wet Mountain area. These rocks include stratified sedimentary beds as well as deposits resulting from igneous activity. Tertiary volcanic tuffs associated with rhyolite flows are light gray to yellow in color. These tuffs contain pumice, Precambrian rock fragments, sanidine, biotite and quartz. Lahars are also present as volcanic mud matrix rocks containing Precamprian metamorphics, Cambrian syenites and andesite.

Tertiary lavas are composed of olivine-rich andesite. This andesite is black to dark green in color and in one area is associated with a basaltic flow. Some andesite is associated with the lahars described above.

Alluvium of Tertiary age, is composed of gray to red poorly-sorted pebbles, cobbles and boulders in a sandy matrix. This alluvium occurs in small quantities in the Wet Mountain area concealing many of the faults. A sandstone alluvium also occurs in the area. This alluvium contains fewer boulders and cobbles than the one previously described although the two are roughly the same age. Clasts are mainly composed of Precambrian basement rocks although some syenite rock fragments are present. Most of this alluvial material formed as channel fill although some could have originated as a form of pediment (Taylor et al, 1975).

Quaternary alluvium is visible in several areas although most has been eroded away. Alluvium of this age exists as landslide or stratified gravel deposits. The landslide materials are yellow-brown to gray unsorted rock fragments of sand to boulder size. Much of this material is clayey and results from earthflow but several of the major deposits result from rockfall and no clay is present. The stratified alluvium is dark gray and silty to sandy. Subangular clasts are composed of metamorphic or igneous rock fragments which form the local basement.

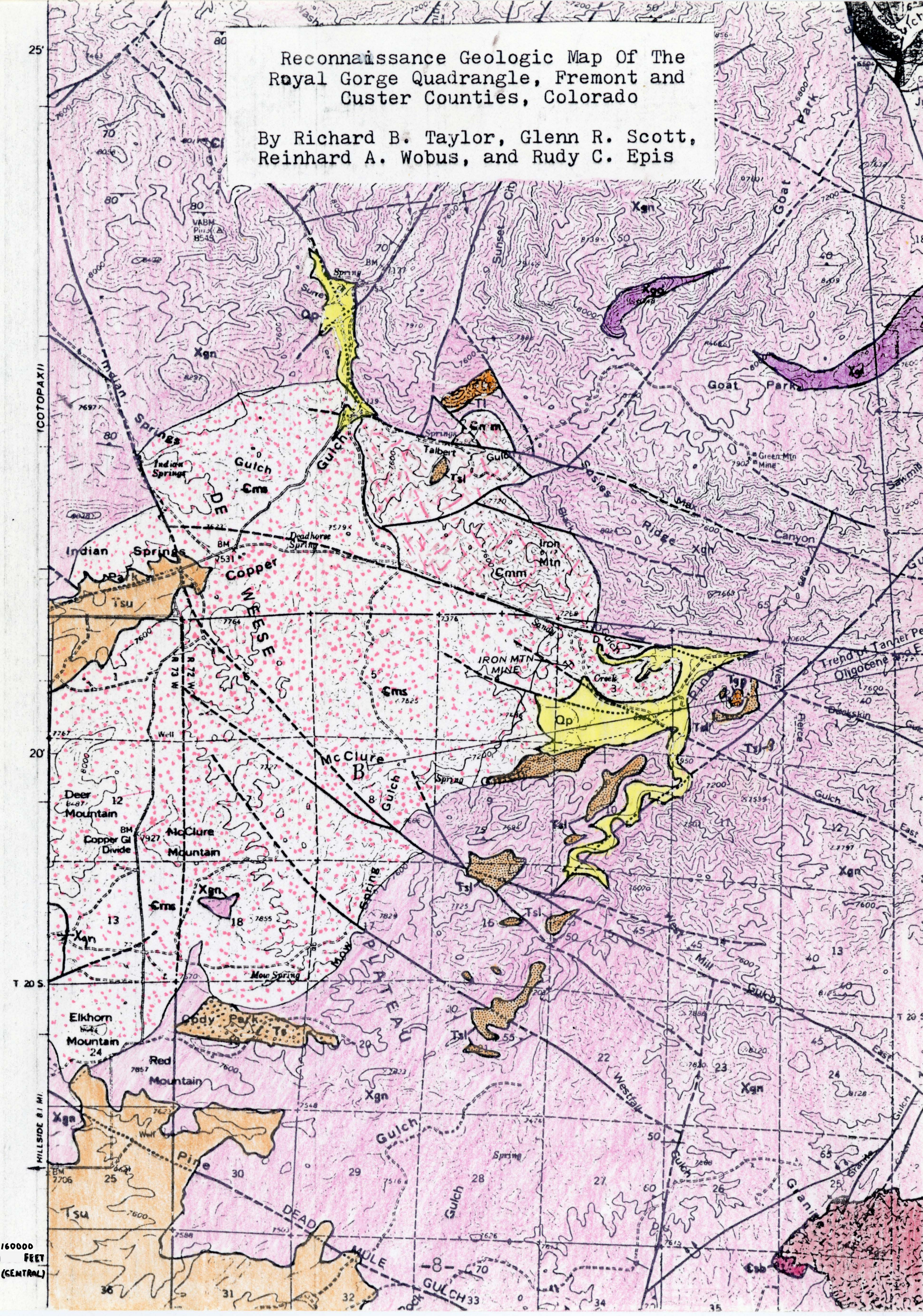
The entire sequence is illustrated in Figure 1, a map of the Wet Mountain area and its associated stratigraphic column. This map by Taylor and others (1975) was the source of much of the information found in this section.

Structure

The Wet Mountains have a complex structure resulting from several periods of igneous intrusion and faulting. Precambrian basement rocks, described previously, were cut

Reconnaissance Geologic Map Of The Royal Gorge Quadrangle, Fremont and Custer Counties, Colorado

By Richard B. Taylor, Glenn R. Scott, Reinhard A. Wobus, and Rudy C. Epis



Qp

PINEY CREEK ALLUVIUM (UPPER HOLOCENE) – Dark-gray silty and sandy humic-rich stratified alluvium containing layers of poorly sorted gravel composed of subangular metamorphic and igneous rocks. Forms flat valley floor along Copper and McClure Gulches in the west-central part of quadrangle. About 10 feet (3 m) thick

Ts

SANTA FE(?) FORMATION (PLIOCENE TO MIOCENE) – Gray to light-brown, sandy to bouldery alluvium that appears to include parts of both the upper and lower parts of the Santa Fe(?) Formation

Tsu

Upper part (Pliocene to Miocene) – Light-brown poorly sorted crudely stratified silty stony sand containing many well-compacted and locally cemented lenses of boulders, cobbles, and pebbles of possible late Miocene to Pliocene age. Cemented by calcium carbonate. Contains several buried Brown soils. Thickness possibly exceeds 100 feet (30 m)

Tsl

Lower part (Miocene) – Gray to red poorly sorted crudely stratified alluvium composed of boulders, cobbles, and pebbles 3 inches to 8 feet (0.1–2.5 m) in diameter in a sandy matrix. Precambrian metamorphic and igneous rocks generally make up most of the deposit; at some localities contains significant amounts of Cambrian syenite and volcanic rocks. Generally distributed along inferred early to middle Miocene stream channels, but may possibly also include pediment-like deposits. Ranges from a thin lag pavement to 100 feet (30 m) in thickness

Tl

LAHARS (OLIGOCENE) – Laharic deposits having volcanic mudstone matrix; pebbles and boulders are composed of andesite, ash-flow tuff, Precambrian pegmatite, granodiorite, and metamorphic rocks, and Cambrian syenite from the McClure Mountain area. Mudflows both underlie and overlie Gribbles Park Tuff at Wolf Park and are intruded by basalt (Tb). Unit includes gravel north of Talbert Gulch beneath Gribbles Park Tuff. Lahars are 50 feet (15 m) thick

€ms

McCLURE MOUNTAIN COMPLEX (CAMBRIAN) – Composite mass of light-gray medium-grained hornblende-biotite syenite and nepheline syenite, with nepheline-rich pegmatitic segregations and dikes. Intrudes rocks of the complex at Iron Mountain

€mm

MAFIC-ULTRAMAFIC COMPLEX AT IRON MOUNTAIN (CAMBRIAN) – Funnel-shaped layered gabbroic complex made up of dark-gray to black clinopyroxene-olivine gabbro interlayered with plagioclase, pyroxene, or olivine-rich differentiates, and cut by discordant mafic and ultramafic intrusions (Shawe and Parker, 1967)

€qs

SYENITE COMPLEX AT DEMOCRAT CREEK (CAMBRIAN) – Composite stock composed chiefly of light- to medium-gray fine- to medium-grained syenite containing small but persistent amounts of quartz (similar to albite granite). Minor amounts of amphibole-rich mafic variants and small amounts of olivine-clinopyroxene gabbro (Christman and others, 1959)

€sb

BRECCIA OF COMPLEX AT DEMOCRAT CREEK (CAMBRIAN) – Intrusive breccia of syenite and metamorphic rock fragments in syenite matrix that forms a local early border phase at the margin of complex

Xgd

GRANODIORITE (PRECAMBRIAN X[1]) – Gray, light-gray to pinkish-gray massive to foliated medium- to coarse-grained granodiorite and lesser amounts of quartz monzonite and quartz diorite. Correlates with Boulder Creek Granodiorite. Forms plutons whose margins are well foliated and are generally concordant or subconcordant to structure of enclosing gneisses. Interiors of plutons are less well foliated or are massive. Chiefly made up of oligoclase-andesine, microcline, hornblende and (or) biotite, and quartz

Xqd

QUARTZ DIORITE (PRECAMBRIAN X) – Dark- to medium-gray massive to well-foliated quartz diorite. Correlates with Boulder Creek Granodiorite. Grades into granodiorite (Xgd) or may be intruded by it; generally found as mafic shell at outer margins of major granodiorite plutons, but may form small independent plutons. Composed of oligoclase and hornblende and lesser amounts of biotite, microcline, quartz, and iron oxides. The Xqd and Xgd intrusive units have been dated by Rb/Sr isochron and have an age of about 1,720 m.y. (million years) (Carl Hedge, written commun., 1971)

Xgn

MIGMATITIC GNEISS (PRECAMBRIAN X) – Layered gneisses, chiefly feldspathic biotite-quartz-plagioclase gneiss with minor amounts of hornblende gneiss, calc-silicate gneiss, and garnetiferous and sillimanitic varieties. Characteristically gray, brownish-gray, or pinkish-tan medium- to fine-grained well-foliated and well-layered rock. Compositional banding generally is parallel to foliation and ranges in thickness from a fraction of an inch to several tens of feet. Variably migmatitic; salmon-pink to white stringers, veinlets, or small tabular masses of quartz-plagioclase-microcline-biotite pegmatite characteristically cut the gneiss or occur as subconformable layers. The association of the sillimanite-microcline pair in rocks of appropriate composition indicates that the high-grade metamorphism reached the uppermost part of the amphibolite metamorphic facies. Late poikiloblastic muscovite indicates local retrograde metamorphism. Unit interpreted as formed from a sedimentary and volcanic sequence principally containing rhyodacitic to intermediate flows and tuffs, together with sedimentary interlayers containing volcanic detritus mixed with other clastic debris by closely spaced deep fractures as a result of arching and doming in the area (Olson et al, 1977). The age of faulting can only be inferred to be Precambrian. This fracture pattern, with two sets of faults oriented roughly N30W and N30E, influenced the emplacement of alkalic igneous rocks during several intrusive episodes spanning the late Precambrian and early Cambrian.

Two sets of faults are present in the Wet Mountain area. The first group consists of Northwest trending vertical faults. Movement along these fractures occurred during the Precambrian and they were reactivated by the Laramide Orogeny in the late Cretaceous. A set of Northeast trending shear fractures cut lower Proterozoic rocks and were not involved in Laramide activity.

The early Paleozoic was a time of intermittent sedimentary deposition. Sediments of this age, present outside the Wet Mountain area, are flat lying limestones, shales and sandstones. These rocks are inferred to have been present in the Wet Mountains, due to regional subsidence during the Paleozoic, but their presence has been obliterated by erosion in this area.

During later Paleozoic time, two major uplifts occurred. The Front Range Geanticline was raised in Mississippian and Permian times whereas farther south, the Uncomphagre Geanticline rose during the Pennsylvanian and Permian. Between these structures lay the Colorado Trough in which Pennsylvanian and Permian sediments accumulated to a thickness of 3000 meters (King, 1977).

The Mesozoic and Cenozoic were also times of sedimentary deposition resulting from several periods of continental subsidence and transgression. These rocks, along with those formed in the Paleozoic, were eroded following block faulting associated with late Cretaceous Laramide activity. A horst, in the central Wet Mountains, has left exposed the Precambrian and Cambrian igneous rocks which this study encompassed whereas, to the east and west, down faulting left younger rocks exposed. The Wet Mountain Graben, to the west of the Wet Mountains, left recent alluvium exposed along with Tertiary volcanics, sediments and intrusives,

The block faulting on the eastern side of the Wet Mountains is associated with the Ilse Fault. One of many faults in the area to trend N30W, this fault was active during the Precambrian igneous emplacement and was reactivated by the Laramide Orogeny. During the Laramide, the east wall moved down creating a fault line scarp which is presently 1000 to 2000 feet high in the south but diminishes to the north, finally dissappearing. The Precambrian rocks east and west of this fault differ in composition and cannot be correlated. To the east, biotite gneisses and granitic gneisses occur whereas, to the west, hornblende gneisses are exposed.

Two large intrusive bodies occupy the Wet Mountain area. The McClure Mountain Complex, in central Fremont

County, is composed of faulted Cambrian intrusives. This pluton is roughly circular and 5 to 6 miles in diameter. A smaller pluton comprises the Democrat Creek Complex 4 miles to the southeast. This pluton is less faulted and roughly a mile in diameter. Both intrusive bodies are Cambrian in age.

The McClure Mountain Complex

Two major centers of igneous intrusion are present in south central Colorado. These are the Powderhorn District and the McClure Mountain Complex 135 km to the east (Olson et al, 1977). The McClure Mountain Complex is an alkalic intrusive body roughly circular in plan. This complex is cut by radiating faults, cutting the concentrically distributed rocks at high angles (Parker and Hildebrand, 1962). The entire complex is centered around McClure Mountain and occupies an area of approximately 20 square miles (Taylor et al, 1975). This area is shown in Figure 2.

In the McClure Mountain Complex, alkalic igneous rocks have discordantly intruded gneisses, amphibolite and other Precambrian metamorphics. These intrusives cut across the foliation of the metamorphic rocks so they are younger than the regional metamorphism (Shawe and Parker, 1967). Armbrustmacher and Hedges have noted that host rocks adjacent to these intrusives are generally fenitized. The fenite was developed from a quartzo-feldspathic host rock by the removal of quartz and the replacement of the original feldspar by potassic feldspar.

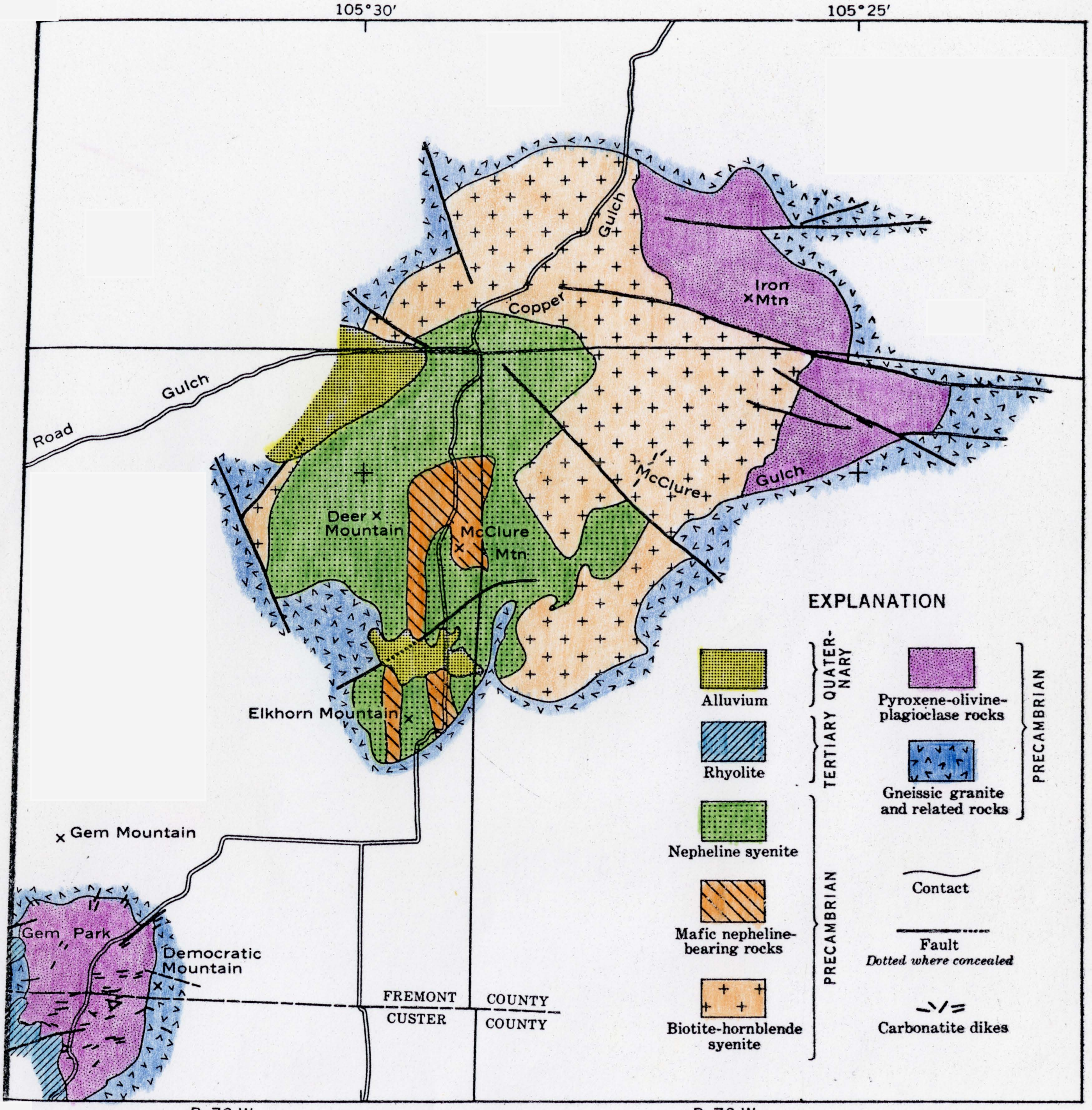


Figure 2:

181.1.—Generalized geologic map of the alkalic rocks at Gem Park and McClure Mountain, Fremont and Custer Counties, Colo. Unpatterned area not mapped.

All authors agree that cross cutting relations suggest the hornblende syenite to be older than the nepheline syenite. They disagree, however, on how the ages of the two compare as well as their origins. This will be discussed later.

Rocks found in the McClure Mountain Complex contain differing proportions of the principal minerals plagioclase, pyroxene, olivine and magnetite and include various types of syenite, mafic nepheline-bearing rocks and gabbro (Shawe and Parker, 1967). Thin section analysis of some of the rocks found in the complex can be found in the Appendix.

Gray pyroxine-olivine-plagioclase rocks form the eastern border of the McClure Mountain Complex (Parker and Hildebrand, 1962). These rocks lie next to hornblende-biotite syenite. This syenite is medium grained and gray to pink in color. Alkali feldspar present in this rock shows a perthitic structure. Nepheline-bearing rocks are mostly gray in color. These rocks are extremely variable in texture and grain size and grade from mafic to felsic (Olson et al, 1977). Feldspar-pyroxene-olivine-hornblende-biotite gabbro plugs occur throughout the complex.

Mineral deposits sited within the complex include sodium niobate, vermiculite and thorium (Parker et al, 1962). Carbonatite sills occur in the complex as white to red-brown rocks composed of calcite or dolomite. These rocks are found in greater quantities within the Iron Mountain portion of the complex (Shawe and Parker, 1967).

Surrounding the McClure Mountain Complex on several sides are the Pinon Peak Breccia Pipes. This breccia is composed of Precambrian gneiss fragments in a matrix of calcite, potash feldspar, crocidolite, aegerine, hematite and quartz (Heinrich and Dahlem, 1967). The composition of this breccia varies greatly from place to place.

Carbonatites also occur in the area. They are found where veins adjoin or lie within basaltic dikes as small plugs (Singewald and Brock, 1956). Spencer and others (1978) believe this injection to have been an explosive event.

Olson and others (1977) believe that older mafic and ultramafic rocks were cut by younger, related, syenitic rocks. They note the cross cutting relations between hornblende-biotite syenite and nepheline syenite but feel the ages of the rocks differ by less than 1m.y. (as inferred from radiometric age dating of the two syenites). Parker and Hildebrand (1962) agree that all syenitic rocks are comagmatic.

An alternative theory (Armbrustmacher and Hedges, 1982) suggests a variety of magmas were present which originated from different source materials. Rare earth element concentrations in the nepheline syenite suggest they could not have been derived from the same magma as that of the hornblende-biotite syenite. They go on to say that mafic-ultramafic rocks and hornblende-biotite syenite have similar $^{87}Sr/^{86}Sr$ ratios whereas nepheline syenite and carbonatite have similar ratios which differ from those of the first two. They suggest that the hornblende-biotite syenite and the mafic/ultramafic rocks could have fractionated from a mafic magma whereas the nepheline syenite and carbanatite formed from another magmatic source.

Heinrich and Dahelm (1967) have suggested the following as a sequence of events in the McClure Mountain Complex.

	Within Complex Itself		Within Dike Halo
		11.	Fenitization (local)
10.	Carbonatites (rare)	10.	Carbonatites (abundant) Pinon Peak Breccias
9.	Lamprophyres (rare)	9.	Lamprophyres (abundant)
8.	Nepheline Syenite Dikes	8.	Nepheline Syenite Dikes
7.	Nepheline Syenite		
6.	Ijolite		
5.	Syenite and Trachyte Dikes (abundant)	5.	Syenite and Trachyte Dikes (rare)
		4.	Fenitization
3.	Syenite		
2.	Gabbro		
1.	Peridotite and Magnetite Ilmenite Rock		

Table 2: Sequence of Events in the McClure Mountain/Iron Mountain Complex, Colorado.

Several theories as to the origin of central Colorado igneous bodies have been postulated. One theory suggests the movement of crust westward over a stationery hot spot or, conversely, the migration of a localized center of volatile enrichment under the crust (Olson et al, 1977).

Radiometric age dating of the two bodies supports this theory since igneous rocks of the McClure Mountain Complex are roughly 50m.y. younger than those found in the Powderhorn District. However, no igneous rocks occur between the two bodies. If they did occur, which according to this theory they should, igneous rocks would be visible in the Precambrian X rocks exposed between the two igneous bodies. An alternative theory (LeBas, 1971) suggests that both the igneous emplacement and faulting were a result of tensional forces within the crust. This tension arose as a result of upbulging and swelling of crustal material.

Origin of the Nepheline Syenites

Nepheline-bearing rocks are characterized by silica undersaturation. These rocks are found in areas of crustal stability, block faulting or moderate folding (Hyndman, 1972). Two theories prevail as to the origin of these nepheline-bearing rocks. These theories are limestone assimilation and magma differentiation.

Limestone assimilation is the interaction of limestone and magma through the dissolution of limestone. In order to attain equilibrium, a reaction must occur between the wall rock and magma.

The addition of limestone to a silicic magma brings about the desilication of the magma. This occurs as calcium carbonate reacts with the magma to form calcium-bearing silicates. Removed with the silica are iron, magnesium and aluminum as more complex calcium silicates are formed. The undersaturation of the magma allows the formation of nepheline.

The alternative theory of syenite formation involves partial melting of the mantle. Low degrees of partial melting yield alkalic basaltic magmas that are thoroughly undersaturated. Nepheline-bearing mafic rocks crystallized from such a magma are nephelinites, ijolites and related nepheline-bearing rocks. These nephelinites may occur with carbonatites and kimberlites in which case CO_2 is an important constituent of the magma and source rock. Crystallization of the magma, mainly pyroxenes and olivines, yields differentiates that include small quantities of nepheline syenite and phonolite (its extrusive equivalent).

A problem arises with this theory in explaining the formation of large syenitic complexes. This problem concerns the size of some of the complexes (including the McClure Mountain Complex) and the great quantity of magma necessary to generate this silica undersaturated complex. Even with such a problem, partial melting is the most popular theory for explaining the formation of nepheline syenites.

In the McClure Mountain Complex, the limestone assimilation theory is impossible. This is because the occurrence of limestone in the area is nowhere recorded in the literature. Magmas intrude Precambrian gneisses containing little or no calcium carbonate. Any $CaCO_3$ in the area is not of sufficient quantity to change the composition of the magma an appreciable amount.

Field associations in the McClure Mountain Complex show the association of nepheline syenite, other nepheline-bearing rocks and carbonatites (Parker and Hildebrand, 1962). This genetic relationship is also demonstrated by similar, low $^{87}Sr/^{86}Sr$ ratios (Armbrustmacher and Hedges, 1982) and by the occurrence of unusually large amounts of Zr, Th, U, Nb, Sn, Be and rare earth elements (Barker, 1983).

These associations could be explained through partial melting within the mantle. Partial melting would lead to the formation of nepheline syenites and nepheline-bearing rocks by the processes mentioned above. Carbonatites would form from calcium carbonate present in the magma and source rock. The assimilation of limestone would not be necessary.

Conclusions

The McClure Mountain Complex is a fairly typical example of an ultramafic, nepheline-bearing complex. One of several intrusive complexes in south-central Colorado, the McClure Mountain Complex contains rocks which cover the range of rocks normally found in such alkaline complexes. These rocks include ijolites, nepheline syenites and carbonatites.

Rocks found in the McClure Mountain Complex lack the variety typical of other alkaline complexes. Whereas other complexes contain pyroxenites, lamprophyres and kimberlite dikes, sills and plugs, these have not been found in the McClure Mountain Complex. It is, however, the authors belief that these rocks may be present in the area and will be discovered with more extensive investigations.

Whereas many alkaline complexes exhibit concentric zoning, this is not as evident in the McClure Mountain Complex. Many authors, however, argue for its existence. A ring of metasomatism surrounds most alkaline complexes. However, the McClure Mountain Complex fails to show this feature.

Lack of information concerning field relations in the McClure Mountain Complex is quite evident. Further study of this complex is sure to uncover interesting data on both this complex and alkaline complexes in general.

APPENDIX

Olivine Gabbro

This gabbro is a course grained holocrystalline rock. Feldspar occurs in twinned grains. Some grains also show reverse zoning. Much of the feldspar is dusted with highly disseminated opaque material. Olivine is present in grains slightly altered to serpentine. Hornblende and biotite grains are both highly corroded but only the biotite has altered to chlorite. Neither of these elongate minerals show orientation. Both hornblende and biotite have replaced the pyroxene. Magnetite occurs in grains both associated with augite and independently.

Feldspar. Plagioclase is present as grains averaging 0.5mm. Most are anhedral to subhedral with spare euhedral grains oriented parallel to (010). The plagioclase occurs in twinned grains. These twins are albite and combined albite/carlsbad; zoning is ubiquitous and several grains show reverse zoning. Plagioclase composition is oligoclase, $An_{15}Ab_{85}$.

Clinopyroxene. Clinopyroxene grains are anhedral and reach 3mm in diameter, although most grains are 2mm or less. Neutral grains show very little to no pleochroism. Clinopyroxine present is augite. Magnetite and plagioclase are enclosed in some augite crystals.

Olivine. Olivine occurs in anhedral to subhedral grains reaching 3mm across, but averaging 1.5mm. The crystals are colorless to tan. Many of the olivine grains show slight to moderate alteration to serpentine, possibly of the variety antigorite. 2V is 87 and so the composition of the olivine is forsterite.

Hornblende. Hornblende grains average 1.5mm but reach 3mm in length. Grains are pleochroic with X=tan, Y=green-brown, Z=brown. In some places the hornblende has replaced the pyroxine.

Biotite. Biotite grains average 2mm in length. These grains are pleochroic: α=tan, γ=brown to red-brown. Many of these grains are highly altered to chlorite while some have replaced pyroxine.

Accessories. Magnetite is the only accessory mineral present. It is found in grains less than 0.75mm in length. Some grains occur within augite but most are scattered throughout the rock.

Secondary Minerals. Chlorite and serpentine occur as secondary minerals. The chlorite shows pleochroic greens but most is highly corroded so the exact grain size is undeterminable. Serpentine is found in colorless grains cut into the olivine. These grains are extremely small with individual grains averaging 0.25mm.

Fabric. Hypidiomorphic-granular

Rock Name. Olivine Gabbro

Composition.

Oligoclase	30%
Clinopyroxene	23%
Olivine	15%
Hornblende	15%
Biotite	7%
Secondary Minerals	7%
Accessories	3%

MM1-A Gabbro

Clinopyroxene comprises most of this rock in grains intergrown with amphibole. Many of these grains show simple twins. Hornblende grains are highly corroded and show no orientation. Magnetite and carbonate are scattered throughout this holocrystalline rock. Magnetite also occurs in highly disseminated grains dusting the augite.

Clinopyroxene. Augite is the clinopyroxene present in grains averaging 2mm across. Much of this augite shows intergrowths of needles of amphibole of an unknown composition. Most of these neutral to yellow grains exhibit simple twins and a few are zoned. Much of the magnetite present is associated with augite.

Hornblende. Anhedral grains of hornblende reach 0.5 mm in length. Pleochroism is X=tan, Y=light brown, Z=red brown. These grains are highly corroded.

Accessory Minerals. Accessory minerals include magnetite, apatite and sphene. Magnetite grains are subhedral to euhedral and average 0.5mm. Apatite and sphene are both rare. Apatite grains are subhedral to euhedral and less than 1mm. Sphene is anhedral averaging 0.5mm.

Fabric. Hypidiomorphic-granular

Rock Name. Gabbro

Composition.

Augite	90%
Hornblende	5%
Accessories	5%

MM2-A Syenite

This syenite is medium grained and holocrystalline. Alkali feldspar occurs in grains intergrown with albite and potash feldspar. Hornblende is present as elongate grains although much of the hornblende is more prismatic. Scapolite is also present. These grains are prismatic showing three directions of cleavage. Accessory minerals include sphene, apatite and magnetite. Hematite is a secondary mineral replacing magnetite.

Alkali Feldspar. Orthoclase is present in grains averaging 1mm in length. These anhedral to subhedral grains show intergrowths with albite and potash feldspar.

Hornblende. Hornblende grains are elongate to prismatic and average 2.5mm in length. Pleochroic scheme is X=yellow, Y=green, Z=brown. Many of these grains have been replaced by alkali feldspar. Some grains show twin seams.

Scapolite. Scapolite grains average 1mm across. These six sided grains show fair relief and are uniaxial negative. Two distince cleavages are visible, at roughly 90° to each other. A third cleavage is 45° to the first two. No twins are observed.

Accessory Minerals. Magnetite, apatite and sphene are accessory minerals in this rock. Magnètite occurs in subhedral grains averaging 1mm across. Apatite grains are subhedral averaging 0.5mm in length. Sphene is also subhedral. These grains average 0.75mm. All of the accessory minerals are found scattered throughout the rock.

Secondary Minerals. Hematite is present as a replacement of magnetite.

Fabric. Hypidiomorphic-granular

Rock Name. Syenite

Composition

Alkali Feldspar	40%
Scapolite	30%
Hornblende	20%
Accessory Mineral	9%
Secondary Mineral	1%

MM2-B Syenite

This syenite is almost entirely composed of alkali feldspar which occurs as grains showing extensive intergrowths of potash feldspar and albite. Hornblende is present as are small amounts of biotite and muscovite. None of these elongate grains show orientation. Along with biotite and muscovite, other accessory minerals include magnetite and sphene. Alteration of the feldspars has produced the secondary mineral, kaolinite.

Alkali Feldspar. Alkali feldspar occurs in anhedral grains reaching 4mm across. These grains show intergrowths of albite and potash feldspar. Orthoclase exhibits simple twins whereas microcline, present in small amounts, shows its characteristic quadrille structure. Much of the alkali feldspar present has been altered to kaolinite.

Hornblende. Anhedral to subhedral grains of hornblende are up to 5mm in length. Pleochroism is X=yellow, Y=greenish brown, Z=dark green-brown. Many of the crystals are corroded and replaced by feldspar. Much magnetite occurs associated with hornblende and is an alteration.

Accessory Minerals. Accessory minerals include biotite, muscovite, magnetite and sphene. Biotite and muscovite occur in small quantities scattered throughout the rock. In many places, alkali feldspar has replaced areas within the biotite grains. Both biotite and muscovite grains average 0.5mm. Muscovite is less corroded than the biotite. Magnetite occurs throughout the rock but is mostly found associated with the hornblende.

Secondary Minerals. Feldspar grains are strongly altered to kaolinite.

Fabric. Hypidiomorphic-granular

Rock Name. Hornblende Syenite

Composition.

Alkali Feldspar	70%
Kaolinite	15%
Hornblende	10%
Accessories	5%

MM3 **Biotite Foidite**

Much of this holocrystalline rock is composed of nepheline as a background material. Hornblende and biotite also occur in relatively large quantities. Hornblende grains are prismatic and elongate. In some places these grains have been replaced by biotite. Hematite occurs in rather large rounded grains.

Hornblende. Hornblende grains average 1.5mm in length. These grains are elongate and prismatic showing two distinct directions of cleavage. Pleochroism is slight with all colors ranging in the greens. Hornblende is found associated with biotite and apatite and in some places has been replaced by the biotite.

Nepheline. Nepheline is present in euhedral to subhedral grains averaging 0.75mm. These grains combine to form a background material of this rock. Nepheline is uniaxial negative with low birefringence and low relief. No cleavage is visible of these grains.

Biotite. Biotite grains range from less than 0.5mm to over 4mm. These grains are pleochroic with α=yellow, γ=red brown. The larger grains are highly corroded and contain apatite. Smaller grains have replaced hornblende.

Accessory Minerals. Apatite and sphene are accessory minerals in this rock. Apatite is subhedral to euhedral. Grains average 0.5mm across. Sphene is less abundant than apatite. Sphene grains are subhedral to euhedral averaging

0.7mm across. Both sphene and apatite are found associated with hornblende and biotite.

Secondary minerals. Hematite is the only secondary mineral present. It is possibly a replacement of magnetite once present in the rock.

Fabric. **Hypidiomorphic-granular**

Rock Name. **Biotite Foidite**

Composition.

Hornblende	40%
Nepheline	30%
Biotite	20%
Accessories	8%
Secondary Minerals	2%

MM5 Hornblende Biotite Syenite

This holocrystalline rock is coarse grained. Alkali feldspar has exsolved albite and shows simple twins. Some of the feldspar has been altered to sericite and some shows late stage replacement. Biotite and hornblende occur in highly corroded grains. Neither of these elongate minerals shows orientation. Accessory minerals present include magnetite, apatite and sphene.

Alkali Feldspar. Orthoclase is present in large grains reaching 3mm in length. These grains are subhedral to anhedral and show simple twinning. This alkali feldspar has exsolved albite forming a perthitic structure.

Biotite. Biotite is present in highly corroded plates up to 3mm in length. Pleochroism is α=yellow-green, γ= green-brown. These subhedral to euhedral grains show no orientation. Many are associated with sphene.

Hornblende. Anhedral to subhedral grains of hornblende average 1.5mm in length. Pleochroic scheme is X=yellow, Y=greenish brown, Z=brown. Many of these grains are highly corroded.

Accessory Minerals. Accessory minerals include magnetite, apatite and sphene. Magnetite grains are anhedral to subhedral and average 1mm. Most are found associated with biotite although a few grains are interspersed throughout. Sphene grains average 0.5mm. They are subhedral and show no cleavage. Like magnetite, sphene is found associated with biotite. Apatite grains are up to 1mm in subhedral to euhedral grains.

Secondary Minerals. Alkali feldspar grains are slightly altered to sericite. Hematite is also a secondary mineral found in small rounded grains.

Fabric. **Ophitic**

Rock Name. Hornblende-biotite Syenite

Composition.

Alkali Feldspar	70%
Biotite	10%
Hornblende	6%
Accessories	10%
Secondary Minerals	4%

MM6-A Syenite

This syenite is a coarse grained holocrystalline rock. Alkali feldspar composes most of this rock in grains exsolving albite. These grains show simple twinning and some are zoned. Quartz occupies the interstaces between some of these grains. Hornblende occurs in highly corroded grains associated with magnetite, sphene and hematite.

Alkali Feldspar. Alkali feldspar is present in subhedral grains up to 3.5mm in length. Some of these grains show zoning and albite twinning. Much of the alkali feldspar present has exsolved albite in a perthitic structure.

Hornblende. Hornblende grains are highly corroded and average 1.5mm. Pleochroic scheme is X=yellow-green, Y=olive green, Z=green. Hornblende is found associated with magnetite and sphene.

Quartz. Quartz occurs in angular grains averaging 0.5mm. These grains occupy the interstaces between the alkali feldspar grains.

Accessory Minerals. Sphene and magnetite are accessory minerals in this rock. Sphene is subhedral to anhedral and less than 0.25mm in length. Magnetite grains are mostly subhedral. These grains average 0.5mm where associated with hornblende and slightly larger where independent.

Secondary Minerals. Hematite is present as a replacement of magnetite.

Fabric. Hypidiomorphic-granular

Rock Name. Syenite

Composition.

Alkali Feldspar	75%
Hornblende	10%
Quartz	10%
Accessories	4%
Secondary Minerals	1%

MM7 Precambrian Country Rock

This rock is holocrystalline and medium grained. Biotite and plagioclase range from anhedral to euhedral although most are subhedral. Feldspars and quartz with granoblastic texture form most of the rock, whereas biotite and accessory minerals are scattered throughout. Biotite lacks orientation.

Biotite. Biotite is present in plates reaching 1mm. The pleochroic scheme is α=light brown, γ=green to brown. These grains show few crystal faces although those present are oriented parallel to (010). Some biotite grains contain bands of magnetite.

Plagioclase. Subhedral crystals range from 0.5 to 1mm long. Most twinning present is of the albite variety but several grains exhibit albite/carlsbad twins. No zoning was observed. Extinction angles suggest the plagioclase present have the composition $An_{12}Ab_{88}$. Nearly all grains showed some alteration to sericite although a few are highly weathered.

Alkali Feldspar. These subhedral to anhedral grains average 0.5mm across. Both microcline and orthoclase are present although the microcline is rare. Both varieties are highly weathered to sericite with orthoclase the most weathered of the two.

Quartz. Quartz occurs in anhedral grains averaging 0.75mm across. These grains are subangular and subrounded.

Accessory Minerals. Accessory minerals include sphene, apatite, magnetite and muscovite. Sphene occurs in anhedral grains reaching 3mm across. None of the grains exhibit the characteristic euhedral form and partine directions are not visible. Apatite grains are elongate and average 0.75mm in length, the longest reaching 1mm. Magnetite is euhedral to anhedral and occurs either singly of in bands within biotite. Muscovite grains are elongate and reach 1mm. Many of these grains are highly corroded.

Fabric. Granoblastic Texture

Rock Name. Biotite-plagioclase gneiss

Composition

Biotite	30%
Plagioclase	30%
Quartz	20%
Alkali Feldspar	10%
Accessories	10%

MM82 Carbonatite

This rock is almost entirely carbonate in irregular crystals. It is composed of granular aggregates of carbonate with small amounts of either apatite or cancrinite interspersed throughout.

Carbonate. The carbonate present is calcite, determined by a HCl test performed on the rock. These grains are irregular averaging 0.5mm across.

Accessory Mineral. The second mineral present is either apatite or cancrinite. This mineral is uniaxial negative with low birefringence. Some grains are euhedral and hexagonal although most are anhedral and irregular. This would suggest that the mineral present is not apatite since apatite tends to form euhedral grains. The second possibility is cancrinite. However, since I was unable to determine this minerals refractive index, it was impossible to determine this mineral to be cancrinite.

Fabric. Granular

Rock Name. Carbonatite

Composition.

Carbonate	98%
Accessory Mineral	2%

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